

### 3.6 Representative Duty Cycles

Vehicle duty cycles are described in Section 2.8. In order to compare fuel use and emission rates, cycle-average emission rates are estimated based on selected duty cycles. In this section, the distributions of normalized MAP based on time and fuel use for each representative duty cycle are presented.

For backhoes, there were three observed real-world duty cycles including “mass excavation,” “material handling,” and “load truck.” The cumulative frequency of normalized MAP for the three representative duty cycles for a backhoe is shown in Figure 14. For the “load truck” cycle, a backhoe uses the front bucket, which is 5 times larger than the rear bucket, to place soil or rock into a dump truck. Each duty cycle must be completed in a short amount of time. The operator usually moves the soil or rock with the full capacity of front bucket. Thus, among the three duty cycles, the average engine load for “load truck” is relatively higher than the other duty cycles.

The observed duty cycles for a front-end loader include “rock handling,” “soil handling,” and “load truck.” The cumulative frequency of normalized MAP for the three representative duty cycles for a front-end loader is shown in Figure 15. The average engine loads for these three duty cycles are similar.

In Figure 16, two representative duty cycles for a motor grader are characterized by a frequency distribution of normalized MAP. The two cycles observed, “resurfacing” and “shouldering,” have substantially different average engine loads. The “resurfacing” cycle has a higher average engine load compared to the “shouldering” cycle because of the resistance of the blade on the ground surface while a motor grader works.

The distribution of normalized MAP based on time and fuel use for each observed duty cycle for a backhoe is shown in Figure 17. The left panel of the figure is the distribution of time for each duty cycle, and right panel of the figure is the distribution of fuel consumption. Similar figures for a front-end loader and a motor grader are shown in Figure 18 and Figure 19, respectively.

For the “load truck” cycle of backhoes shown in Figure 17, the lowest five MAP modes contribute to about 60% of time but only contribute to less than 50% of fuel consumption. High MAP modes consume more fuel, resulting in high emission rates of NO, opacity, HC, and CO. The lowest five MAP modes for the “mass excavation” cycle contribute to more than 90% of time and fuel consumption because the “mass excavation” cycle has the lowest average engine load among these duty cycles. The lowest five MAP modes for “material handling” contribute to about 90% of time and 80% of fuel consumption. In general, lower MAP modes contribute to more time but less fuel consumption and higher MAP modes contribute to more fuel consumption but less time.

The lowest MAP mode of the “load truck cycle” for front-end loaders contributes to 25% of time but only contributes to less than 10% of fuel consumption shown in Figure 18. For the motor grader cycles shown in Figure 19, the highest five MAP modes of the “resurfacing” cycle contribute to 60% of time and 80% of fuel consumption compared to 15% of time and 35% of fuel consumption for the “shouldering” cycle.